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TCS-1404-63/KH
9 May 1963

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MEMORANDUM FOR: Executive Director, NPIC

SUBJECT: Present Status of the Univac 490 System

A. BACKGROUND

1. The Univac 490 computer system has as its raison d'etre its use as the information processing (or computational) element, or sub-system, within a larger system which we have been referring to as the "Photo-Measurement System" (PMS). The Photo-Measurement System has the simple goal of providing the photo-interpreter a capability for obtaining metrical information from present day photography with the same ease he enjoyed in days long past when aerial photography was, for the most part, taken in a nominally vertical position with a camera that had the same mathematical model as a box Brownie. In that situation measurement of ground distances or determination of lengths from photography was accomplished by using measurements made with tube magnifier or boxwood scale as the input data and a slide rule (or paper and pencil) as the computational element. The mathematical model was embodied in the two easily remembered equations:

Grd. distance = Photo distance x scale no.
and
Scale no. = Flying height divided by focal length

2. This simplicity is now apparently gone forever, the geometrically simple camera being now supplanted by systems wherein the film lies on some slice of the surface of a cylinder, different parts of the same frame are exposed at different instants of time, the lens moves during that time with relation to the film and does so with a varying rate, and the whole camera system is carried in a vehicle whose position in space changes greatly during the period required to expose one frame. Consequently the mathematical model now becomes a lengthy series of equations even when expressed in the compact notation of vectors and matrices. The two parameters, focal length and flying height, that were sufficient to describe a particular frame in the primitive case are now supplemented by a long list of items such as scan rate, IMC cam constant, lens velocity vector, vehicle velocity vector, Coriolis acceleration vector, geocentric position vector of exposure station, etc. Just as the complexity of the mathematical model indicates the use of a digital computer as the computational element in a present day system, the proliferation of parametric values required by that model implies that an efficient system will provide for maintaining a file

490 SYSTEM

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GROUP 1
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of the values of these parameters for each frame of photography and for the automatic incorporation of these parameters into the appropriate mathematical model by merely referencing the unique identification of the photograph. Given the present and projected rates of input of new photographic materials to this Center the provision, maintenance, and automatic utilization of such a file gives rise to the concept of a single central file which, effectively, can be accessed automatically by any user of the system. Conceptually it would be possible to have a computer for each user with each such computer having automatic access to this large central file. This, at least, is less staggering than the prospect of providing both the large central file and computer for each user. The provision of asynchronous access to the central file would almost certainly require that the file be under the direct control of a central master computer to sequence the queries against it as well as to handle the maintenance of the file itself. A further disadvantage of the "multiple-small-computer" approach is that it would, we believe, tend to increase the problem of hardware maintenance and would also force the users of such systems to function as computer operators in addition to their duties as analysts. Thus, the third possible alternative was chosen:

A central file under the control of a central processor of sufficient capacity and speed to be able to handle the computational requirements of all users of the system. The computer chosen as being best suited for use in the computational element of this system was, of course, the Univac 490. Since it is a general purpose digital machine it can, potentially, be put to many other uses. And, indeed, one of the most important features of the U-490 is that it is possible to make concurrent use of much of its capability for such "other uses". It is important in considering the Univac 490 to clearly distinguish between its prime use as an element of a larger system and its "other" (i.e. "computation-center" type) uses.

B. PRESENT STATUS

1. The overall system can, rather arbitrarily, be broken down into three major areas or sub-systems:

a. Remote station equipments

b. Communications sub-system

c. Information processing sub-system (N.B. that the information processing function subsumes the computation function.

It must be pointed out that these subsystems stand in a rather complex inter-relationship to each other. Changes in one sub-system may be

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reflected in all of the others. It is convenient to discuss these sub-systems in somewhat different order than the one given above (which stems from the ordering of information flow).

COMMUNICATION SUB-SYSTEM: The general method of tying remote stations to the central computer site was worked out early in the project and the special cabling required was "hardened" into the building during its reconstruction. The initial complement of central site equipment (Scanner/Selector, Communications Control Units, patch panel, modem units) is on hand and checked out.

REMOTE STATIONS EQUIPMENT: At the time the letter-of-intent for the computer hardware was issued no design work had been done on any remote station equipment. There was in effect, however, a contract with [redacted] for the production of "Measuring Viewers" under the specification that their output must be "compatible" with whatever computer system was selected as a follow-on to the Alwacs in use at that time. Compatibility had, to that point, been interpreted only to mean that the output of the device would be in a machine-readable form acceptable to the particular computer finally selected. Since this device was conceived by all parties to be basically an extension of the [redacted] viewers that were being built for the sole purpose of studying new inputs in the early exploitation phases, the idea of providing a connection to the computer rather than paper tape output accorded well with the basic premise that the remote station equipments should be extensions of the equipments on which the analyst would normally study the film. The format of the output and the details of the comms interface were worked out and supplied to [redacted] It is understood that output format and comms interface have not contributed to any degree to the slippage that has occurred in this production of the first such device. The principal problem they seem to be encountering is in the design of the coordinate measuring system itself. It is understood that [redacted] has recently given an oral commitment of 30 May 1963 for the completion of the prototype instrument. In view of the work accomplished to date on the machine this date may be rather optimistic.

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Plans and Development Staff has issued specifications and request for proposal (RFP) for a viewer with measuring capability to serve the same functions as the [redacted] and has received several proposals in response. According to [redacted] two of these proposals look "very promising" in terms of their mechanical design and likelihood of achievement in the time indicated in the RFP. [redacted] has informally indicated to the companies proposing that a PERT reporting procedure will be made a part of the contractual arrangement.

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The Huston-Fearless Dual-Screen Measuring Projector (DSMP) falls in the category of "other uses" of the computer system since it is not, by any stretch of the imagination, suitable for general P-I analyst use. However, because it seemed likely that this would be a "work-horse" instrument for TID/TAB, it seemed advisable to connect the DSMP on-line to the 490 as a means of maximizing the productivity of the DSMP by eliminating most batch processing of its output. The communication formats and electronic interface of the DSMP were defined to be identical to those spelled out for the [redacted] equipments, and the processing logic for messages from it, is an extension of the logic worked out for the [redacted] Consequently we will be able to check out the processing logic and procedures by treating the DSMP as if it were a [redacted] The arrival of the DSMP is now scheduled for 15 April. 50X1 50X1 50X1

INFORMATION PROCESSING SUB-SYSTEM: This aspect of the overall system can be further subdivided into (1) Hardware, and (2) Programming. The status of the first (Hardware) can be summed up by saying that the initial complement of Univac supplied equipment has been delivered and installed. An interim 30-inch incremental plotter is being manufactured and a 60 x 60 inch plotter has been selected for eventual incorporation into the system. The 30 inch incremental plotter is being configured in such manner that it can, when the 60 x 60 inch is delivered, be moved to a remote location in one of the analyst working areas and be used solely for the production of planimetric representations of entities being measured by the analysts using the system.

The initial programming goal (2) was keyed to the initially planned complement of remote station equipment and the incremental plotter. In retrospect it is realized that the basis for time estimates for attaining this goal were in terms of the progress that we had made in those areas that were considered the major problem areas in the system and program design activities, such as the "Real-Time Control" program. To explain why a routine called "Real-Time Control" (RTC) is a major problem area in comparison to, say a routine modeling a particular camera system (which was the type of major problem area encountered with the Alwac system) one could attempt an analogy (admittedly crude) to the problems that might be encountered by the manager of an organization that suddenly goes from being a small purely research establishment of, say, 25 people to being an establishment of perhaps 500 people and now having a manufacturing function as well as an expanded R&D function. In the first instance communication within the organization would not be a major problem. There might not even be any formal channels of communication. Even if there were it could be assumed that the manager also availed himself of the various informal channels of communication within his organization and was quite fully conversant with the work being done by his group. In this case the manager's

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major problems are, in general, the problems encountered by the individuals in his group and the extensions and consequences of these problems. In the expanded organization the manager must now face two problems that did not previously exist (at least as major problems) in his original organization:

(1) He can no longer be familiar with all details of all aspects of his organization. Consequently its normal functioning must be largely automatic and proceed without his having to be aware of the accomplishment of every action involved in that normal functioning.

(2) The manager now needs to be informed of the exceptions to normal functioning within his organization. To this end there must now be effective and orderly communication channels to report this exception information to him. Normally there must also be horizontal channels of communication for the automatic functioning. Both of these problems might be dismissed as organizational or administrative problems or as "housekeeping" problems. This they are, to be sure, but they are of prime importance to the successful functioning of the organization. Their solutions provide the essential framework in which the work of the organization is accomplished. The Real-Time Control program is analogous to the situation just described in that it provides the essential framework in which the "worker" programs function. In providing this framework it must provide for all the "clerical" record-keeping necessary for making decisions at any point as to what actions are to be taken. Further the Real-Time Control program is, itself, charged with making these decisions at various managerial levels, in order that the system function in an automatic manner. The only exception reporting it should do is to report to computer room operating personnel equipment failures that will require maintenance action. Just as the functioning of the large organization requires efficient communication between various of its components so must the Real-Time Control program provide for communication between various routines and sub-routines to insure the functioning of the various sequencings of these routines which it may establish.

The weakness in this analogy stems from the fact that in the Real-Time Control program there is no possibility of ad hoc decisions -- there must be a pre-established decision procedure and course of action for every contingency that can arise in the operation of the system. This is equivalent to saying that the system is completely formalized, and is in contrast to many a business organization whose actual operating mechanism turns out, under close scrutiny, to be quite different from its "on-paper" formal organization.

The move from our Alwac-centered system of reducing photo-coordinate data by batch processing techniques to the U-490 centered Photo-Measurement

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system is at least of the same order of magnitude as the change postulated for the hypothetical business organization in our analogy. It is perhaps understandable then that we estimated our progress in terms of solutions to problem areas such as the RTC program and tended to dismiss as trivial those areas in which the approach to be taken was obvious for the problem was one of selecting the best of several alternative approaches. Unfortunately the system is not operable until all the links of the chain are forged. Selections between alternative approaches must be resolved by limited manpower on an appropriate time schedule. The most trivial subroutine must be coded as well as the most complex. Each must be checked out. Each must be documented to far greater detail than our past programs were ever documented. Eventually all the component sub-routines, subprograms, and controlling executive program must be merged together and made to function as one complete entity. Then this program that works in a simulated environment must be checked out on the equipment that is actually going to be used, and finally the all-important component, the analyst, must be added and the total "man-machine" system checked out. Before this final check-out stage is reached all the batch programs that support the system must also be formulated, coded, and checked out. We have, we believe, been aware from the start of this project of most of the complexities of the system and of the many activities that would have to be accomplished before the system became operational but lacked a "systematic method" of considering all of these simultaneously to arrive at some measure of the total effort that would be required to reach the goal or of the progress made toward it.

We have been aware of the PERT technique since its inception as a management device in the Polaris weapon system development program, but like many others held the belief that it was applicable only to programs comparable in size to the Polaris undertaking. The first realization that this was not necessarily the case came from the article "Does Pert Work for Small Projects?" in the December issue of Data Processing. Only a few weeks after this, [redacted] arrived at NPIC for his initial review of our operations and aspirations bringing with him not only his highly successful experience in computer-centered undertakings in a wide range of areas but also actual examples of the application of the PERT technique to undertakings comparable in size to that which we are involved in. With his advice and counsel there has now been produced a PERT network which is a reasonable representation of the activities involved, and the constraints between them. In the preparation of this PERT network time estimates were made for appropriate activities (the estimates made by ourselves or by the individuals already directly involved in the activity) and a copy of the PERT network with the information worksheets forwarded to [redacted] He has had several analysis runs made on this information, using his 7090 PERT program, under various assumptions on equipment availability dates, and the listings are here now for review.

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It is emphasized that despite our enthusiasm for PERT it is not a panacea. The process of constructing the network has been extremely valuable in forming a clear picture of where we stand. It is felt that this same process would greatly help other areas to more clearly define their future plans. For example, at the first network attempt it became clear that although many man-hours of effort have gone into programming various facets of the plotting program for the incremental plotter so much remained to be done that this could be the limiting item in the first implementation phase and further that the system could make a substantial contribution without the plotting capability. Accordingly the present network will give maximal return for the time and effort involved.

The goal shown as the ending event (designated Phase I) calls for implementing the distance and height "function" (and some other "by-product" functions) on the prototype viewer, using the soon-to-be-delivered DCMP as a test bed in advance of delivery. The executive portion of the real-time program (referred to as "The Control Program" or "Real-Time Control") has been coded and is well along in the checkout process. It provides for eight remote stations and is "open-ended" in terms of the number of functions it can control (i.e. it is applicable to all functions yet envisaged for the system). It is, in fact, useable for many more than eight stations, the upper limit being determined by the amount of core available for the station-specific tables (i.e. one fixed-location table for each remote station) around which it is organized. Similarly most of the other sub-programs for the phase I-A undertaking have been coded and in some cases partially checked-out (as separate entities) but none will be considered as being through the design phase until the appropriate documentation has been completed, nor will program integration commence until both detailed design specification and checkout products are at hand. Standards and examples for documentation are being freely adapted (plagarized in a more accurate term) from "Milestone" definitions. 50X1 50X1 50X1 50X1

The batch programs that support the real-time system (as contrasted to programs used in responding to an input from a remote station) have the very general functions of establishing and maintaining the frame-organized "Photo-Parameter File". Thus we have in this category programs for reading in the so-called "binary clock" information for each frame, performing various checks and doing as much automatic correction of both random and systematic "clock" errors as possible, correlation of vehicle "clock" time to systems time, computing position of the vehicle for each "clock" reading, accepting horizon measurement information and then computing attitude information for each set of horizon images followed by smoothing of this information and updating the record for each frame by insertion of the smoothing values. Much of the present effort on the KH-6

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system frame ephemeris is salvageable to further the vehicle position determination procedures. It should be noted that whereas we originally envisaged a very crude determination of vehicle position using a Keplerian orbit with subsequent updating on the basis of LMSC computation of a "final frame ephemeris" it now appears possible on the basis of discussion with LMSC to achieve that final accuracy in our initial file creation (for a new mission). LMSC has provided us with a new classic form orbital model that will "mesh" with their computational procedures. When a vehicle is in flight they will supply orbital parameters by cable with each set to hold over several revolutions without significant loss of accuracy. The program will be a substantial bit of computation however. The other important batch computing undertaking is the attitude reduction from horizon images. [redacted] has formulated an excellent and rigorous reduction method that will permit construction of a program that will minimize the work involved in preparing horizon measurement information for input to the machine. A curve smoothing procedure has also been worked out. 50X1

One additional effort should be mentioned. The initial and rather sketchy documentation on the Neliac compiler developed by the Naval Ordinance Test Station (NOTS) and UNIVAC for the NOTS 490 configuration indicates a great extension in the capabilities of the compiler as compared to the original implementation for M-460 "Countess" computer described by [redacted] in his published works on these efforts. At the time the project was initiated it was felt that the NOTS-Neliac version (then just getting under way) would require a great deal of modification and extension before we would be able to use it for anything other than occasional "one-shot" programs. In the intervening months there has been much discussion in the computer field on standardization of programming languages for command and control systems, and the Navy has abandoned its own offspring, Neliac, in favor of the Air Force sponsored JOVIAL language. The outlook for the Neliac language was rather bleak until the issuance of the Air Force sponsored RAND Corporation denouncing any standardization as premature by several years. In the meantime NOTS has carried out most of the major extensions required in the 490 version as far as arithmetic capabilities are concerned. The increase in scope of some of our own computational programs (such as the more refined orbital model) and the seemingly exponential increase in the number of distinct photographic collection systems are strong arguments in favor of using a problem oriented language in our programming effort, even at the possible expense of slight inefficiencies in the resultant object code. Accordingly we are now exploring the possibility of carrying out the requisite further modifications and extensions to Neliac to make it suitable for use as a programming language for our real-time system programming effort. It should be noted that the most popular of all problem-oriented languages, 50X1

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FORTRAN, does not have the capability of expressing all the functions normally required in any real-time application. Further supporting testimony for NELIAC is found in an LMSC proposal relative to the Gemini and Apollo in which they propose to use NELIAC (on the CDC 3600) as the basic programming language.

To conclude this discussion of the programming effort we submit that on receipt of the PERT network runs we will be able to provide a more meaningful and accurate analysis of where we stand.

C. POSSIBLE TRANSFER OF 1401 FUNCTIONS ONTO THE 490 SYSTEM

1. The thought that transfer of 1401 functions onto the 490 system might be feasible stemmed from a consideration prior to implementation of either system of the following three premises:

a. The "real-time" requirement on the 490 system was estimated as requiring not more than 5% of the total time available over any normal working day.

b. The 490 has a full range of standard input/output equipment fully compatible with the 1401 installation (i.e. 80 column cards, 729-IV tape capacity, 600 l.p.m. printer).

c. The use of the executive system, REX, permits both a "real-time" support activity and a normal batch processing operation to go on simultaneously by running the batch program in the intervals (ranging from milliseconds to minutes) between interrupt response action occasioned by inputs from remote stations.

Since the real-time program per se will make no use of the central site input/output equipment (excepting, of course, status messages printed at the console) an obvious conclusion from the above premises is that transfer of the 1401 function is altogether possible.

2. The premises given require further and more detailed consideration and, furthermore, do not constitute a complete listing of the areas that must be considered in making any judgement as to the feasibility or desirability of such a shotgun wedding. We now consider them in depth:

a. The 5% time requirement estimated for the real-time support of the remote stations is only for the real-time worker program itself and does not include the time requirements of the batch programs that directly support the real-time system by maintenance operations on the photo-parameter file. As previously indicated

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some of the programs (orbital computations for example) are far more complex and time-consuming than originally planned. Nor does this figure make any allowance for the time requirement for batch processing of data produced by various off-line equipment within the division. Additionally there are a considerable number of programs for which there is a clear and valid justification that make use of information in the photo-parameter file for part, or even all, of their input data. A few examples are:

(1) Listings of frame ephemeris information.

(2) Production of photo-coverage plots.

(3) Listings of attitude information (irrespective of mode of derivation -- i.e. horizon, inertial platform, or stellar photography).

(4) Production of graphical plots of attitude to support operational groups.

(5) In-flight production of coverage plots for briefing purposes.

b. The various batch programs listed above in amplification of the availability-of-time factor all introduce some measure or other of equipment availability constraint whether running concurrently with the real-time application or separately. Additionally it should be mentioned here that the real time program itself will normally require from four to six tape servos for its own use (we are still trying to devise techniques to reduce this requirement to have more servos free for concurrent operations).

c. The REX system and design philosophy result in several additional restrictions:

(1) REX itself requires ca. 4500 words of core memory out of a total of 16 K words available in our machine.

(2) REX assumes that the "real-time" program is permanently in core. Of course the total real-time program does not have to be in core since the real-time program itself can call in additional segments. As a practical matter these segments must be loaded in an absolute binary into a fixed working area which itself cuts into the amount of core available. At all

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events the resident portion of the real-time program must always include the routine to accept communication from the remotes and the analysis portion of the control routine to analyze the input messages and initiate the appropriate actions to deal with them. A further restriction on the amount of free core stems at this point from the present design of the real time program itself.

3. The real-time program is organized on a station-specific basis, i.e. for each remote station a table is maintained in core, serving a wide range of purposes but essentially functioning as the interface between the stations and the various "worker" sub-programs, all under the direction of the RTC program. As is characteristic of many real-time programs these tables have the property that many entries can be set and/or used by several different routines or sub-programs within the overall real-time system. These tables require a very substantial amount of core. It is recognized that, potentially, expansion of the system can require different approaches than these presently being followed (tables to be on drum, or maintenance of a variable length "station-active" queue of tables, etc.) but we are not trying to provide the "ultimate" system in our first implementation effort.

4. It is not here argued that core limitations prevent transfer of 1401 operations but rather that they would considerably complicate such an operation. The same holds for our own concurrent programs but with a clearer day-to-day picture of system status we probably are in a better position to make adjustments in both the batch and real-time portions of the total effort.

5. Perhaps the most important consideration relative to the two systems is that batch loads for both peak simultaneously. Any merger of the two would almost certainly be detrimental to both activities. The 1401 operation is against critical deadline and the same considerations will hold for the PMS when operational.

6. An additional factor that is difficult to assess precisely but which certainly must be considered is that the PMS itself will not be static. Change will continually be forced upon it from the outside by the development of new collection systems which will give rise to a high time requirement for program maintenance and modification on the PMS itself.

7. The motivation in seeking to merge the two systems is, presumably, economic. Yet in this case we could easily have a substantially increased and continuing programming cost that would stem from the increased complexity of programming for both groups. The increased time required for

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such programming may be even more significant than the increased indirect costs.

8. Our recommendation is that both groups consider partial back-up of their most critical functions but that no merger of the two operations be initiated at this time or even given any further study until the Photo-Measurement system is operational.

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Chief, Technical Intelligence Division

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